Updated Individual Preliminary Comments from Dr. Michael Gooseff and Dr. K. Ramesh Reddy

(as of December 17, 2013)

Dr. Michael Gooseff

Michael Gooseff responses to technical charge questions. All question text copied from provided .pdf and pasted below. Responses are provided in red italics below.

TECHNICAL CHARGE QUESTIONS

Overall Clarity and Technical Accuracy of the Draft Report

1. Please provide your overall impressions of the clarity and technical accuracy of the draft EPA Report, *Connectivity of Streams and Wetlands to Downstream Waters: A Review and Synthesis of the Scientific Evidence*.

In general, the overall clarity of the draft report has been achieved. I noted a few locations in the very long report that need some minor clarification, but it otherwise is a very clearly written report, with the exception of distinguishing groundwater from rivers. I have the bias of being a scientist, so it is a bit difficult for me to determine how well it would/will be understood by non-specialists. However, the extensive effort to include definitions and examples from the scientific literature should go a long way toward properly orienting a non-technical person to the concepts covered. My overall opinion is that the technical accuracy is generally good, given the scope of the topic and the literature considered.

Conceptual Framework: An Integrated, Systems Perspective of Watershed Structure and Function

2. Chapter 3 of the draft Report presents the conceptual basis for describing the hydrologic elements of a watershed; the types of physical, chemical, and biological connections that link these elements, and watershed climatic factors that influence connectivity at various temporal and spatial scales (e.g., see Figure 3-1 and Table 3-1). Please comment on the clarity and technical accuracy of this chapter and its usefulness in providing context for interpreting the evidence about individual watershed components presented in the Report.

Chapter 3 communicates a good conceptual framework for describing the channel vs. the river, wetlands, etc., albeit one that is most appropriate for mesic systems. However, the challenge of this conceptual model is biased by the surface topography of a landscape. Ultimately, hydrologic topology (spatial connectedness of different regions) does not always follow surface topography. This conceptual model is useful for upland or mountainous headwater watersheds, but is less useful for low-land watersheds.

The term 'downstream' should not be confused with 'down-gradient'. The former works well for channel flow discussion and description. The latter is more appropriate for surface water-groundwater interactions.

The definitions are useful and the further discussion of their properties is complete enough to discuss the issues of connectivity among the different parts of the watershed. The suite of connections that were discussed was clear and, for the most part, complete.

One fundamental issue remains with respect to the definition of 'river' and 'stream', which, according to the glossary, include the surface water in channels AND the down-valley-moving water in the subsurface. I greatly appreciate this definition and find it useful for linking the surface water and hyporheic zones. However, my sense is that this is NOT a typical definition of streams and rivers. Thus, when reading this report, it will be likely that, particularly lay readers, will misunderstand the findings because of this lumping of surface water and groundwater adjacent to stream and river channels. I propose two solutions, one of which (or something that addresses the issue) should be embraced. (1) re-define "stream" and "river" to just include open water that is in the channel (as defined by the bankfull condition, or some other criterion, for example). This I believe is more consistent with the general definition of stream/river. The implication for the report here then is that it more carefully distinguish between water in the channel and water in the subsurface. (2) more carefully explain this definition of combined surface and subsurface flows and more carefully describe the implications of this definition. Either way, the use of the term and its meaning needs to be consistent throughout the report. My own opinion is that the latter would be transformative and novel.

Finally, the timescales of hydrologic flow and transport could be better identified or articulated across systems and processes (there are many examples in the hydrologic literature) because these timescales dictate the timescales of connectivity of distal water bodies to river networks. This is mainly an issue with respect to groundwater connectivity.

Lotic Systems: Ephemeral, Intermittent, and Perennial Streams

3(a) Chapter 4 of the Report reviews the literature on the *directional* (*downstream) connectivity and effects* of ephemeral, intermittent, and perennial streams (including flow-through wetlands). Please comment on whether the Report includes the most relevant published peer reviewed literature with respect to these types of streams. Please also comment on whether the literature has been correctly summarized. Please identify any published peer reviewed studies that should be added to the Report, any cited literature that is not relevant to the review objectives of the Report, and any corrections that may be needed in the characterization of the literature.

Chapter 4 is clear and well-written with some excellent examples of particular cases observed around the US. The literature cited is correctly represented and summarized within, though it is not clear what the greater scope is. The two highlighted situations of desert southwest streams (largely ephemeral) and prairie streams provide two distinct situations in which streams appear to be disconnected from landscapes (at the surface). The space-time dynamics of the actual connections is highlighted very well within and provides a good basis for evaluating the challenges to understanding connectivity in the context of functioning watersheds and their ecosystems. Some opportunity is missed, however, to emphasize the changing connections (in space and time) of even perennial streams to watersheds.

3(b) Conclusion (1) in section 1.4.1 of the Report Executive Summary discusses major findings and conclusions from the literature referenced in Charge Question 3(a) above. Please comment on whether the conclusions and findings in section 1.4.1 are supported by the available science. Please

suggest alternative wording for any conclusions and findings that are not fully supported.

The conclusions appear to be well supported by the literature review provided in section 4. I am particularly glad to see some emphasis of cumulative downstream impacts of streams or other wetlands as this is a concept that is often ignored.

Lentic Systems: Wetlands and Open Waters with the Potential for Non-tidal, Bidirectional Hydrologic Flows with Rivers and Lakes

4(a) Section 5.3 of the Report reviews the literature on the *directional (downstream) connectivity and effects* of wetlands and certain open waters subject to non-tidal, bidirectional hydrologic flows with rivers and lakes. Please comment on whether the Report includes the most relevant published peer reviewed literature with respect to these types of wetlands and open waters. Please also comment on whether the literature has been correctly summarized. Please identify any published peer reviewed studies that should be added to the Report, any cited literature that is not relevant to the review objectives of the Report, and any corrections that may be needed in the characterization of the literature.

The focus on 'downstream' connectivity is a bit challenging when discussing lateral influences of landscapes or groundwater on open channel flows of the stream network. Technically, groundwater that is lateral to a stream channel and, for example, contributes water to the channel, is providing water 'down-gradient' (i.e., down the gradient of the water table adjacent to the channel). As soon as that water is in the channel, contributing to discharge, then of course 'downstream' is a more applicable term to be used. My review of this section concluded that the literature that was summarized was done so properly.

The definitions of ephemeral and intermittent, relying on the connection (or absence of connection) of channel water to a water table, is satisfying to me in a hydrologic sense, but it is somewhat difficult to reconcile with source of that flow in the channel (i.e., rain storms vs. snowmelt).

4(b) Conclusion (2) in section 1.4.2 of the Report Executive Summary discusses major findings and conclusions from the literature referenced in Charge Question 4(a) above. Please comment on whether the conclusions and findings in section 1.4.2 are supported by the available science. Please suggest alternative wording for any conclusions and findings that are not fully supported.

The phrasing of section 1.4.2 with respect to riparian groundwater serving as a source to rivers is a bit misleading, in my opinion. I follow (and like) the notion of bidirectional exchanges noted in the summary prior to the itemized points. It is my opinion that this statement should be more clear about the bidirectional exchanges of water in the subsurface. The hyporheic zone is referred to several times throughout this report, yet I get the sense that the authors consider it to be more of a vertical feature than a lateral feature. That conceptual model is incomplete. There are numerous studies that have identified 'water from the open channel' of a river in bank-side wells and more distal wells (e.g., Stanford, J. A.; Ward, J. V., The hyporheic habitat of river ecosystems. Nature 1988, 335, 64-66 note that hyporheos were found in alluvial gravels 2 km away from the river). The

definition (as articulated in the glossary) of both 'river' and 'stream' include groundwater, not just surface water, that is flowing in the same direction as the river (down-valley, I presume). While this is arguably an enlightened definition of these features, it is also an uncommon one. Hence, the exchange of surface water with hyporheic exchange between the channel and hyporheic zones that may be laterally or vertically oriented to the channel is lumped into these definitions of 'river' and 'stream'. My conclusion, based on these definitions, is that the riparian zone overlies a substantial part of rivers and streams.

Lentic systems: Wetlands and Open Waters with Potential for Unidirectional Hydrologic Flows to Rivers and Lakes, Including "Geographically Isolated Wetlands"

5(a) Section 5.4 of the draft Report reviews the literature on the *directional (downstream) connectivity and effects* of wetlands and certain open waters, including "geographically isolated wetlands," with potential for unidirectional hydrologic flows to rivers and lakes. Please comment on whether the Report includes the most relevant published peer reviewed literature with respect to these types of wetlands and open waters. Please also comment on whether the literature has been correctly summarized. Please identify any published peer reviewed studies that should be added to the Report, any cited literature that is not relevant to the review objectives of the Report, and any corrections that may be needed in the characterization of the literature.

I found this section to be organized well and informative, but given that I'm not a wetland scientist, I cannot provide a reasonable evaluation of the scope of the literature here. The potential for connection among water bodies is very high when you view the world through the lens of a groundwater hydrologist. However, the realities of the heterogeneities of the subsurface are the invisible controls that are often difficult to fully characterize at scales that matter to flow directions and rates. I would not advocate for extensive discussion of these controls, but I would propose that they be acknowledged.

I would propose that perhaps a useful framework for considering connectivity between these features and receiving waters is that they are more likely to be connected either hydrologically or biologically, and that the burden of demonstrating non-significance of the connection is probably

Geographic isolation is perhaps a useful concept to describe a group of wetlands that are spatially distal from river networks. However, given the extensive discussion of things like the benefits of isolation, the role of hydrologic connectivity, etc., my perspective is that the use of "unidirectional wetlands" is misleading and suggests a connotation of 1-D system rather than a 3-D spatial framework that is likely to be dynamic through time.

I would propose that the authors of the report take the geographically isolated wetland characterization and further parse it into a set of different types of wetlands that might exist in these locations distal from the river network. That is, it should emphasize that such distal wetlands can be multi-direcitonal vs "uni-directional" (as currently described).

5(b) Conclusion (3) in section 1.4.3 of the Report Executive Summary discusses major findings and conclusions from the literature referenced in Charge Question 5(a) above. Please comment on

whether the conclusions and findings in section 1.4.3 are supported by the available science. Please suggest alternative wording for any conclusions and findings that are not fully supported.

I am particularly struck by the conclusion about the comparison of geographic isolation vs. functional isolation. That is an important point to make, in my opinion, because proximity is not the only qualifier of connectivity. The functional significance of these wetlands is manifest in physical, chemical, and biological contributions to the physical and ecological function of landscapes, and the potential impacts to receiving waters.

I believe that the temporal context of connectivity should be included in this executive summary – e.g., when and for how long are hydrologic or biological connections likely to occur? I expect that there is a distribution of the timescales (temporal length of connection) and timings (annual, seasonal, etc.) these connections.

Dr. K. Ramesh Reddy

Overall Clarity and Technical Accuracy of the Draft Report

1. Please provide your overall impressions of the clarity and technical accuracy of the draft EPA Report, Connectivity of Streams and Wetlands to Downstream Waters: A Review and Synthesis of the Scientific Evidence.

The EPA Water Body Connectivity report is conceptually well developed and written in a style that is understandable to diverse groups of clientele interested in wetlands and riverine ecosystems. The report does very good job in providing many conclusions that are supported by peer-reviewed literature on hydrologic, chemical, and biological connectivity among streams, floodplains, riparian areas, wetlands (including isolated), and rivers. Major emphasis is placed on hydrologic connectivity with an assumption that material transfer follows water flow in these systems. Most part this assumption is justified, albeit very simplistic and does not recognize complex interactions among physical, chemical and biological interactions. I found this report very informative and provide a detailed description of hydrologic processes involved in connectivity.

I found the report too long and very descriptive and often repetitive. It is my understanding that the report will be used as guidelines by USEPA and other governmental agencies to support regulatory process to protect water bodies. For this reason, the report attempts to provide detailed accountability and description of issues related connectivity of these water bodies. I would like see the report focus on key issues and findings with some supporting information. Some detailed description can be in presented in boxes separated from main text. This approach gives the reader to focus on main issues addressed in the report. For example, see may reports published by National Research Council.

I understand the logic for defining wetlands based on hydrologic flowpaths as bidirectional and unidirectional. I am assuming this distinction is based on the connectivity to streams and rivers. Even unidirectional wetlands may be connected to small streams via ground water and channels. So it is difficult to clearly separate the connectivity based direction hydrologic flow path, because of spatial and temporal heterogeneity of groundwater and surface flows and patchiness of wetlands in the watersheds. Use these two terms only to describe hydrologic flowpaths and connectivity of different types of wetlands. If you need to use these two terms, at the minimum present a table showing how currently classified wetland types fit into these two broad groups based on connectivity. For example, where do the bottomland hardwood forested wetlands (that may or may not be directly connected streams) fit into this classification.

USEPA has invested significant resources in developing various documents that describe wetlands in much greater details. Although these documents were not published in journals, they were peer reviewed by experts. I would like to see the current connectivity report use earlier

reports as supporting documents to describe wetlands. Details about these documents can be found at the following site: http://www2.epa.gov/nutrient-policy-data/wetlands-modules

In Chapter 2, clearly define the intended use of this document. Currently the purpose and scope of this document as defined is to review and synthesize available evidence to address three questions related to connectivity of wetlands and streams to downstream water bodies. (1) What are the physical, chemical, and biological connections to and effects of ephemeral, intermittent, and perennial streams on downstream waters? (2) What are the physical, chemical, and biological connections to and effects of riparian or floodplain wetlands and open-waters (e.g., riverine wetlands, oxbow lakes) on downstream waters?, and (3) What are the physical, chemical, and biological connections to and effects of wetlands and certain open-waters that lack bidirectional hydrologic exchanges with downstream waters (e.g., most prairie potholes, vernal pools), hereafter referred to as unidirectional wetlands, on downstream waters?

The report addresses these questions with major emphasis on the role of hydrology related connectivity wetlands and streams to rivers. Obviously water flow is a key to connectivity between these ecosystems including material transfer from one ecosystem to others. The report, however, does not adequately address sediment-water interactions in streams and soil-water-vegetation interactions in wetlands. Many of the biogeochemical processes are superficially mentioned.

Much of the literature on wetlands and rivers in southeastern US, especially Florida and Louisiana is missing. This should be addressed in the report.

It would have been useful to have some discussion on how external drivers such as climate change (precipitation, drought, and temperature), landuse change (urban and agricultural activities), and sea level rise will affect hydrologic, biogeochemical, and biological connectivity. Although, the focus of the report is on connectivity related to water quality, other effects including the influence of connectivity on greenhouse gas emission and sequestration macro-elements including carbon should recognized.

A brief discussion of ecosystem service values and tradeoffs associated with functions of wetlands, streams, and rivers should be included in the report.

Conceptual Framework: An Integrated, Systems Perspective of Watershed Structure and Function

> ***Charge Question 2.*** *Chapter 3 of the draft Report presents the conceptual basis for describing the hydrologic elements of a watershed; the types of physical, chemical, and biological connections that link these elements, and watershed climatic factors that influence connectivity at various temporal and spatial scales (e.g., see Figure 3-1 and Table 3-1). Please comment on the clarity and technical accuracy of this chapter and*

its usefulness in providing context for interpreting the evidence about individual watershed components presented in the Report.

Include an Abstract for this chapter as it done for chapters 4 and 5.

Section 3.2- Introduction to River System - Primary focus of this section is on hydrology in river systems. This is section is well-written. I do not have expertise to provide useful comments on this section. There are other experts in the panel who are better qualified to provide comments on this section.

Section 3.3. Influence of streams and wetlands on downstream waters. This section addresses material fluxes from wetlands and streams into downstream waters.

Depending on hydrologic conditions, wetland soils and stream sediments can potentially function both as sources and sinks for macro-elements. Internal fluxes of macro-elements (such as carbon, nitrogen, phosphorus, and sulfur) and other elements should be considered in the discussion.

For example, wetlands serve as sink for nitrate nitrogen and source for ammonium nitrogen. In addition wetlands can also serve as dissolved organic matter (DOM), organic and inorganic phosphorus, metals complexed with DOM, and pesticides. Wetlands can serve as sink for sulfates, nitrate, and elements (carbon, nitrogen, and phosphorus) and pesticides associated with particulate matter. Wetlands accrete various contaminants in soils and serve as long-term storage.

Biogeochemical processes show high degree of spatial and temporal heterogeneity. These processes have major impact on downstream water quality. Biogeochemical hot spots are areas (or patches) can occur in small streams and wetlands and show disproportionately high reaction rates relative to the surrounding area. Cumulative effect of these reactions can be significant for streams and wetlands to function as sinks for contaminant removal.

Discussion on hydrologic connectivity is very good, but the linkage of hydrologic connectivity to biogeochemical connectivity needs further discussion.

Lotic Systems: Ephemeral, Intermittent, and Perennial Streams

Charge Question 3(a). *Chapter4 of the Report reviews the literature on the directional (downstream) connectivity and effects of ephemeral, intermittent, and perennial streams (including flow-through wetlands). Please comment on whether the Report includes the most relevant published peer reviewed literature with respect to these types of streams. Please also comment on whether the literature has been correctly summarized. Please identify any published peer reviewed studies that should be added to the Report, any cited literature that is not relevant*

to the review objectives of the Report, and any corrections that may be needed in the characterization of the literature.

This chapter is well written with respect to physical processes (water flow and sediment and wood transport in the water, and temperature).

Section 4.4.1
Chemical connectivity for most of part well described. When discussing nitrogen removal rates, it is important to distinguish nitrogen species (nitrate, ammonium, or organic nitrogen). What is the relative proportion of each of these nitrogen species? Many places the report refers to nitrogen loss or removal. I am assuming much of this nitrogen is nitrate and the loss is referred to denitrification. This should be clarified and processes regulating removal of nitrate, ammonium, and organic nitrogen should be discussed.

It is worth noting that nitrogen removal is inversely related to mean stream depth. Each of the nitrogen species may respond differently to stream depth and flow. Streams with shallow water depth present a greater interaction of chemicals with benthic sediments as compared to streams with deeper water column. There should be some discussion on the residence time of water in streams.

Similarly, phosphorus removal and associated processes are not well described. What is the range of phosphorus concentrations in different streams and rivers? How the phosphorus removal is affected by stream depth and flow.

Sediment bound nitrogen and phosphorus needs to be discussed. Sediment bound nitrogen includes both organic nitrogen and ammonium nitrogen. Sediment bound phosphorus includes both organic and inorganic forms. This discussion is missing from the text

Section 4.4.2
Dissolved organic matter (DOM) and particulate organic matter (POM) transport is well described. Again, the processes and the factors regulating the breakdown of DOM and POM are described superficially. It should be noted the DOC is not the same as DOM. It should not be interchanged. In addition to carbon, DOM and POM also includes organic nitrogen and organic phosphorus. What is the role of biotic and abiotic process in regulating the breakdown of DOM and POM?

Section 4.4.3.
The title ‘Ions’ is misleading. Refer this section to ‘Electrical Conductivity or EC” that refers to ‘Ionic Strength’. There is not much useful information presented in this section. The EC values provide an idea on how cations and anions composition is affected by streams flows. This section needs additional literature.

Section 4.4.4

This section is also a mixed bag. Need some careful revision of this section. Identify what contaminants are included in this section. Are these metals, toxic organic compounds, or others.

> ***Charge Question 3(b).*** *Conclusion (1) in section 1.4.1 of the Report Executive Summary discusses major findings and conclusions from the literature referenced in Charge Question 3(a) above. Please comment on whether the conclusions and findings in section 1.4.1 are supported by the available science. Please suggest alternative wording for any conclusions and findings that are not fully supported.*

Consider revising 1.4.1 section. It is very descriptive and the message is lost. It should be written in bulleted form, with most of the detailed explanations presented in the main text. Specifically, I am referring to findings "d" and "e". Findings were primarily focused on nitrogen and it is my assumption that report refers to nitrate.

Finding should include sediment bound nutrients, DOM and POM, and other contaminants.

Lentic Systems: Wetlands and Open Waters with the Potential for Non-tidal, Bidirectional Hydrologic Flows with Rivers and Lakes

> ***Charge Question 4(a).*** *Chapter 5 of the Report reviews the literature on the directional (downstream) connectivity and effects of wetlands and certain open waters subject to non-tidal, bidirectional hydrologic flows with rivers and lakes. Please comment on whether the Report includes the most relevant published peer reviewed literature with respect to these types of wetlands and open waters. Please also comment on whether the literature has been correctly summarized. Please identify any published peer reviewed studies that should be added to the Report, any cited literature that is not relevant to the review objectives of the Report, and any corrections that may be needed in the characterization*
> *of the literature.*

Classifying wetlands as unidirectional and bidirectional is adding more confusion in this report. See my earlier comments of the use of this terminology.

Riparian/floodplain wetlands are classified under both bidirectional and unidirectional and all other wetlands are considered unidirectional. I am not sure this type of division is justified and adds unnecessary confusion to the discussion on connectivity. Depending on landscape scape position, many wetlands can have both types of hydrologic flows. In my opinion, it will be best to keep the wetlands group simple as described in other EPA documents.

Riparian areas not considered as wetlands (or do not meet the wetland criteria) should be included in Chapter 4.

Wetland connectivity to streams and rivers is lot more complex (and not well studied) than connectivity of streams to rivers.

Table 5-1 is very good. It summarizes various functions in wetlands. Note that sink and transformation are not the same and they refer different things.

Sink or Source- For example, when nitrate fluxes from water column into underlying soils, then soils act sink for nitrate, while water column acts as source of nitrate. Similarly, soils or sediments can serve as source of phosphorus.

Transformation function – is a biogeochemical reaction mediated biotic and abiotic processes. For example, nitrates are used as an electron acceptor by facultative or anaerobic microbes and convert it to nitrogen gas (denitrification) or to ammonium (dissimilatory nitrate reduction ammonia). Depending on redox conditions, both reactions transform nitrate to different end products.

Physical, chemical, and biological influences of riparian/floodplain areas are adequately addressed. Additional discussion on influence of hydroperiod of wetlands should be included in this section. How changes in hydroperiod affect the source or sink function in these wetlands needs further discussion

A short section on basic macro-elemental cycles (carbon, nitrogen, phosphorus, and sulfur) will be very useful to the reader to see links between sources, sinks, and transformations. Include basic schematic drawings of these cycles, similar to drawing in the report on hydrologic processes.

Depending on the hydrologic connectivity, riparian/floodplain soils exhibit a range of redox conditions, thus regulating cycling of macro-elements, metals, and organic compounds. Spatial and temporal variability in redox conditions can create hot spots and hot moments and disproportionately alter nutrient and contaminant removal rates in the system. It is important some discussion is included to address this topic.

> ***Charge Question 4(b).*** *Conclusion (2) in section 1.4.2 of the Report Executive Summary discusses major findings and conclusions from the literature referenced in Charge Question 4(a) above. Please comment on whether the conclusions and findings in section 1.4.2 are supported by the available science. Please suggest alternative wording for any conclusions and findings that are not fully supported.*

Conclusions are justified based on the literature presented in the report.

Lentic systems: Wetlands and Open Waters with Potential for Unidirectional Hydrologic Flows to Rivers and Lakes, Including "Geographically Isolated Wetlands"

> ***Charge Question 5(a).*** *5(a) Section 5.4 of the draft Report reviews the literature on the directional (downstream) connectivity and effects of wetlands and certain open waters,*

including "geographically isolated wetlands," with potential for unidirectional hydrologic flows to rivers and lakes. Please comment on whether the Report includes the most relevant published peer reviewed literature with respect to these types of wetlands and open waters. Please also comment on whether the literature has been correctly summarized. Please identify any published peer reviewed studies that should be added to the Report, any cited literature that is not relevant to the review objectives of the Report, and any corrections that may be needed in the characterization of the literature.

See my comments for Riparian/floodplain wetlands (see **Charge question 4a**). Many of these comments are pertinent to this section also.

I recommend that Chapter 5 is reorganized as follows, by including following major topics. This will avoid duplication and confusion and focus on wetlands and their connectivity to streams.

a) Types of wetlands (riparian/floodplain wetlands, swamps, freshwater marshes (including isolated), peatlands, and others)
b) Hydrologic connectivity (bidirectional and unidirectional or hydrologic gradient)
c) Chemical and nutrient influences and connections
d) Biological connections
e) Interaction between hydrologic connectivity with chemical and biological connections
f) Major findings and conclusions

Charge Question 5(b). *Conclusion (3) in section 1.4.3 of the Report Executive Summary discusses major findings and conclusions from the literature referenced in Charge Question 5(a) above. Please comment on whether the conclusions and findings in section 1.4.3 are supported by the available science. Please suggest alternative wording for any conclusions and findings that are not fully supported*

Conclusions are justified based on the literature presented in the report.